US006082406A

United States Patent [19]

Williamson, Jr. et al.

[11] **Patent Number: 6,082,406**

[45] **Date of Patent: Jul. 4, 2000**

[54] **PNEUMATIC PILOT-OPERATED CONTROL VALVE ASSEMBLY**

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[21] Appl. No.: **08/909,420**

[22] Filed: **Aug. 11, 1997**

[51] **Int. Cl.**^{7} **F15B 13/043**

[52] **U.S. Cl.** **137/627.5**; 137/596.16; 137/596.18

[58] **Field of Search** 137/596.16, 627.5, 137/596.18; 91/433, 457

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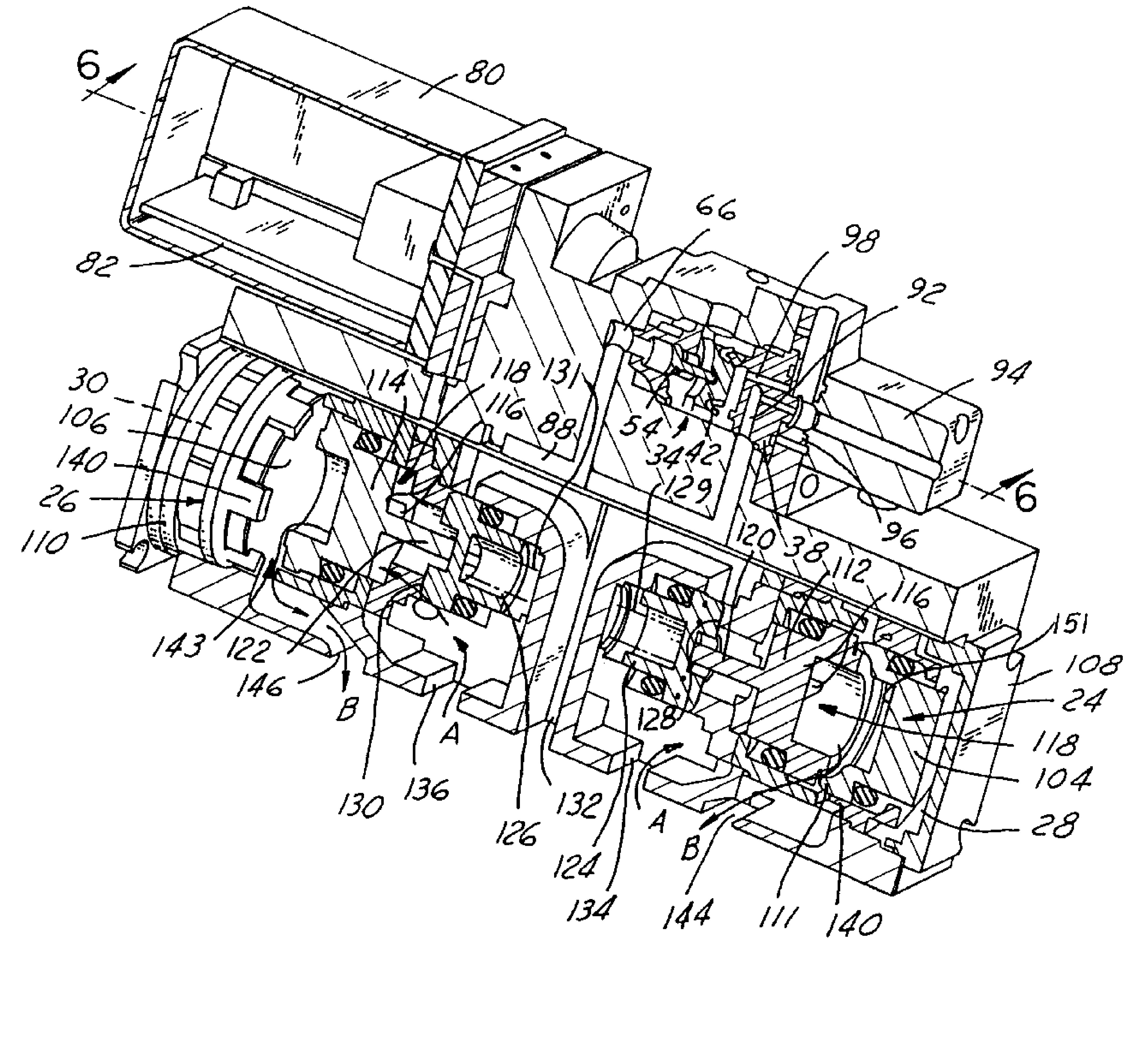
Attorney, Agent, or Firm—Gifford, Krass, Groh, Sprinkle, Anderson & Citkowski, P.C.

[57] **ABSTRACT**

A pilot operated and pneumatically driven control valve assembly has a pair of pilot operated and pneumatically driven regulators to control the pressurization and venting of a pneumatic cylinder. The pilots of each regulator are alternately driven by a pair of normally open pilot operated valves each of which is in communication with a separate regulator to control the pressurization of that regulator. The pressure acting on the pilot of each regulator controls the flow of air through the regulator and the subsequent magnitude of the pressure within the pneumatic cylinder. Thus, varying the pressure in the pilot of the regulator varies the resulting pressure in the pneumatic cylinder in proportion to the pilot pressure. The pilot operated valves are alternately driven between open and closed positions to alternately drive the pilots of the regulators. The regulators communicate with opposed sides of a piston of a pneumatic cylinder to control the pressurization of the cylinder adjacent each side of the piston. The pneumatic cylinder may be of any type with one current application used to drive the clamp of a welding gun of an electrical resistance welder such as that used in an automotive assembly line.

3 Claims, 8 Drawing Sheets



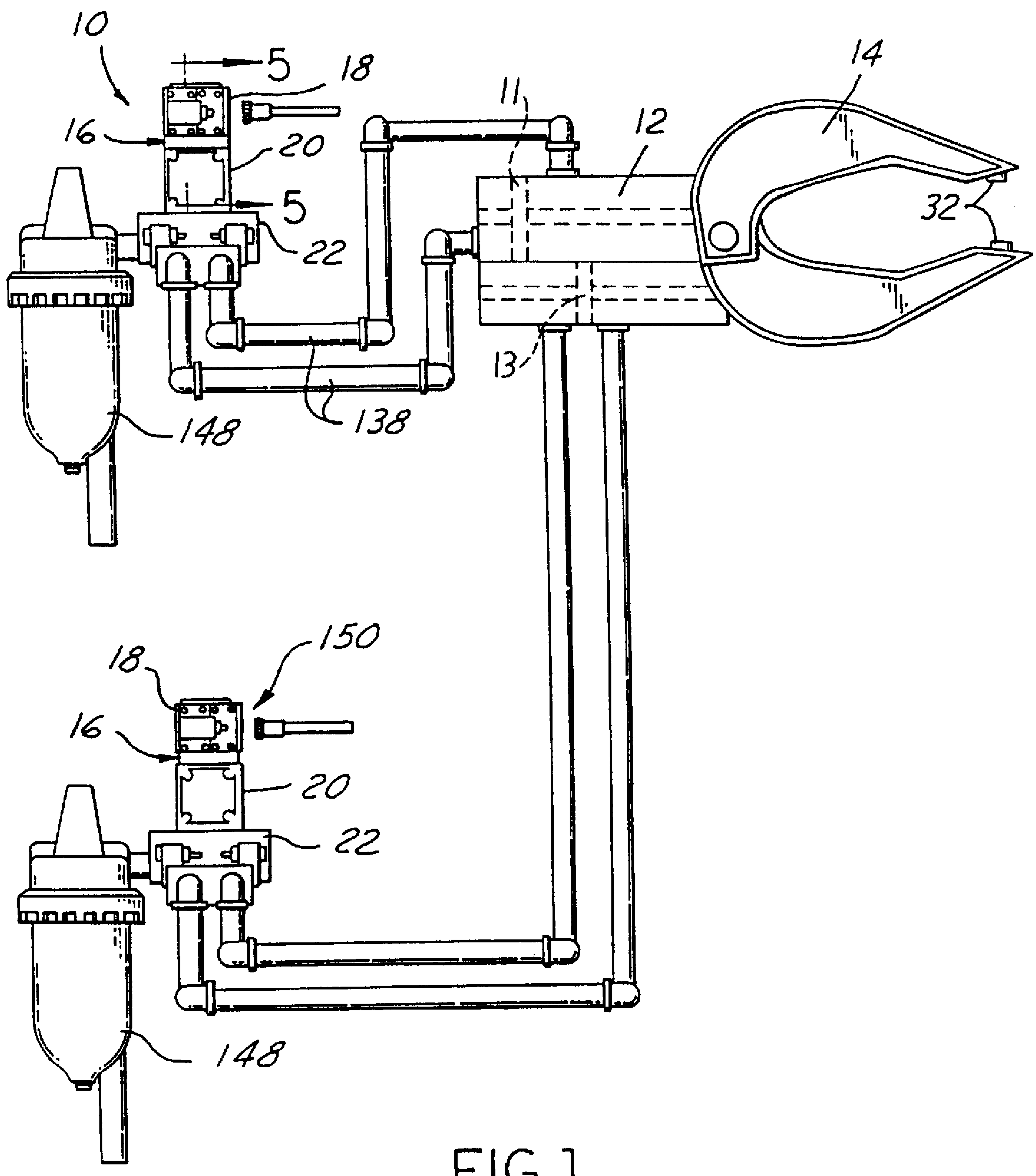


FIG.1

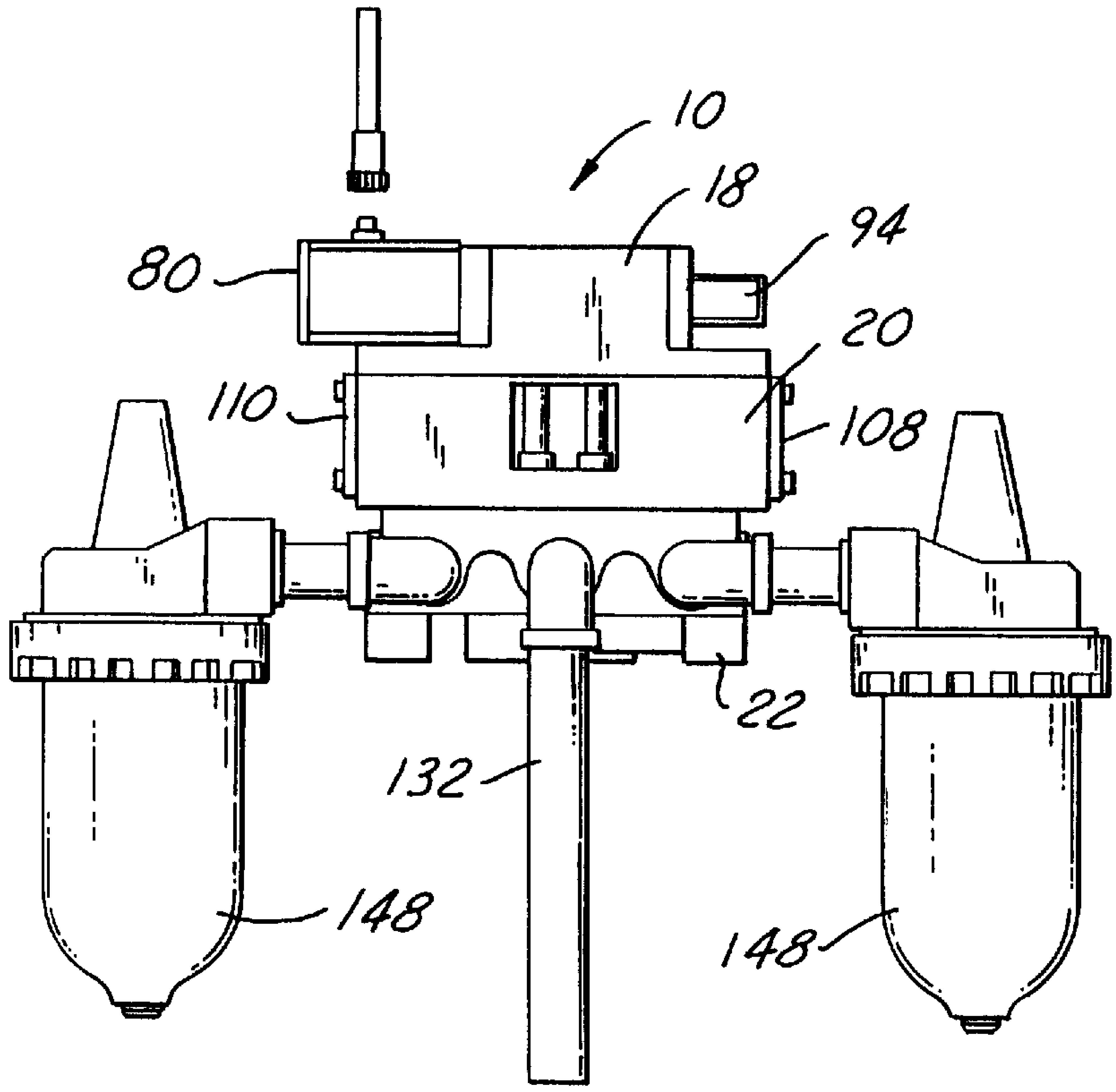

10
18
80
94
20
110
108
22
132
148
148

FIG. 2

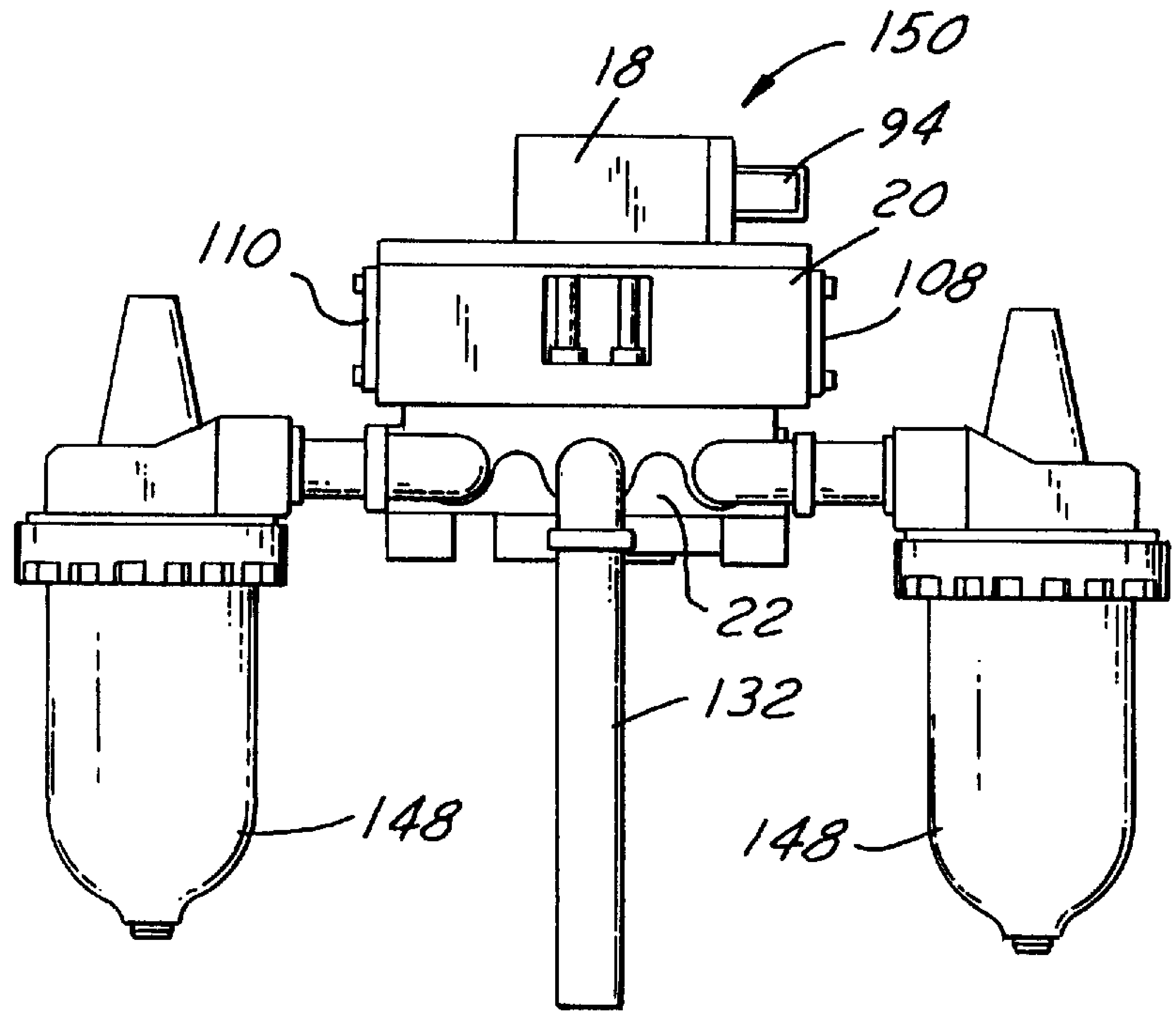

150
18
94
20
110
108
22
132
148
148

FIG. 3

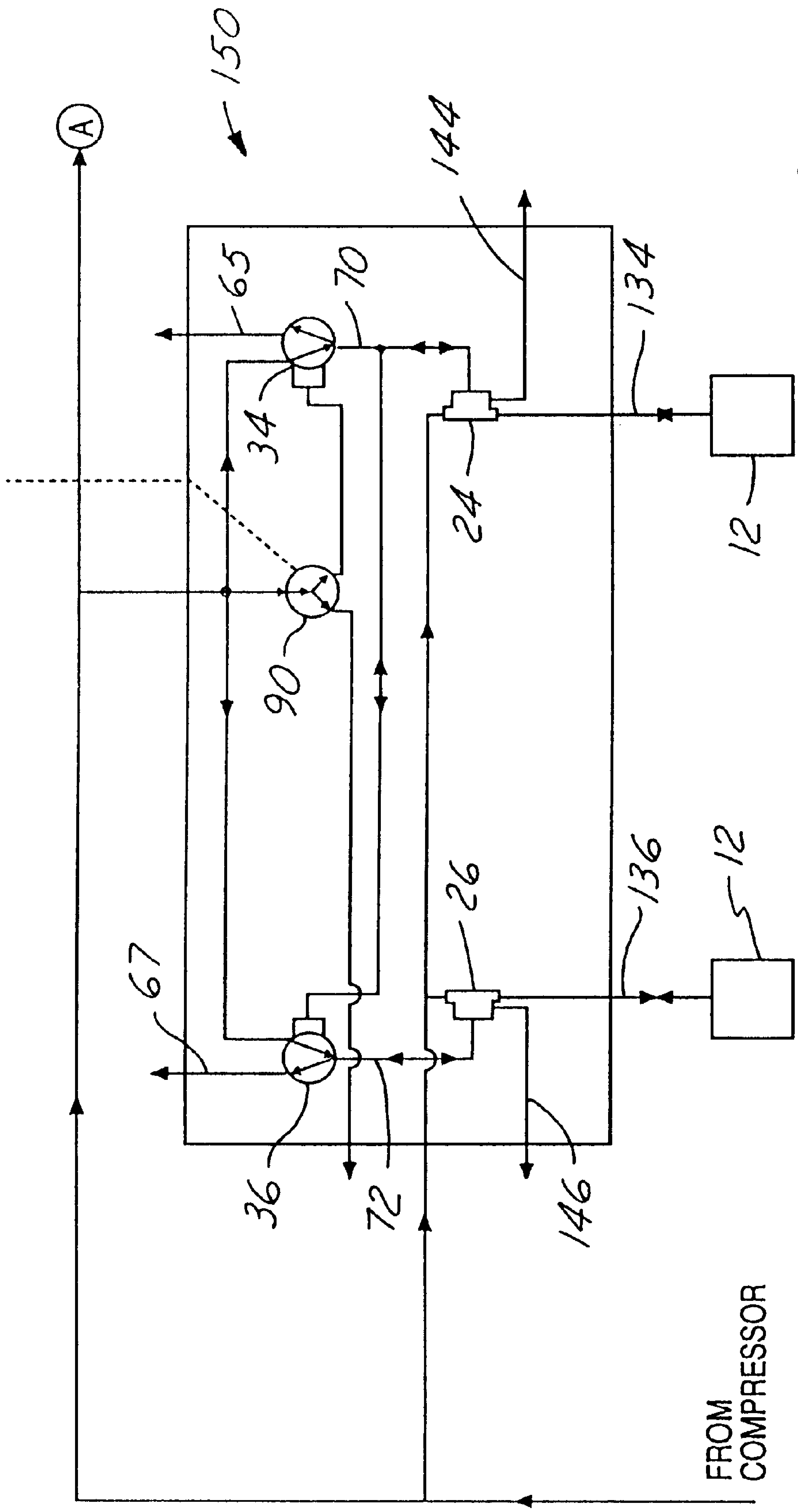

A
150
144
65
70
134
34
24
12
90
67
26
136
12
36
72
146
FROM COMPRESSOR

FIG. 4A

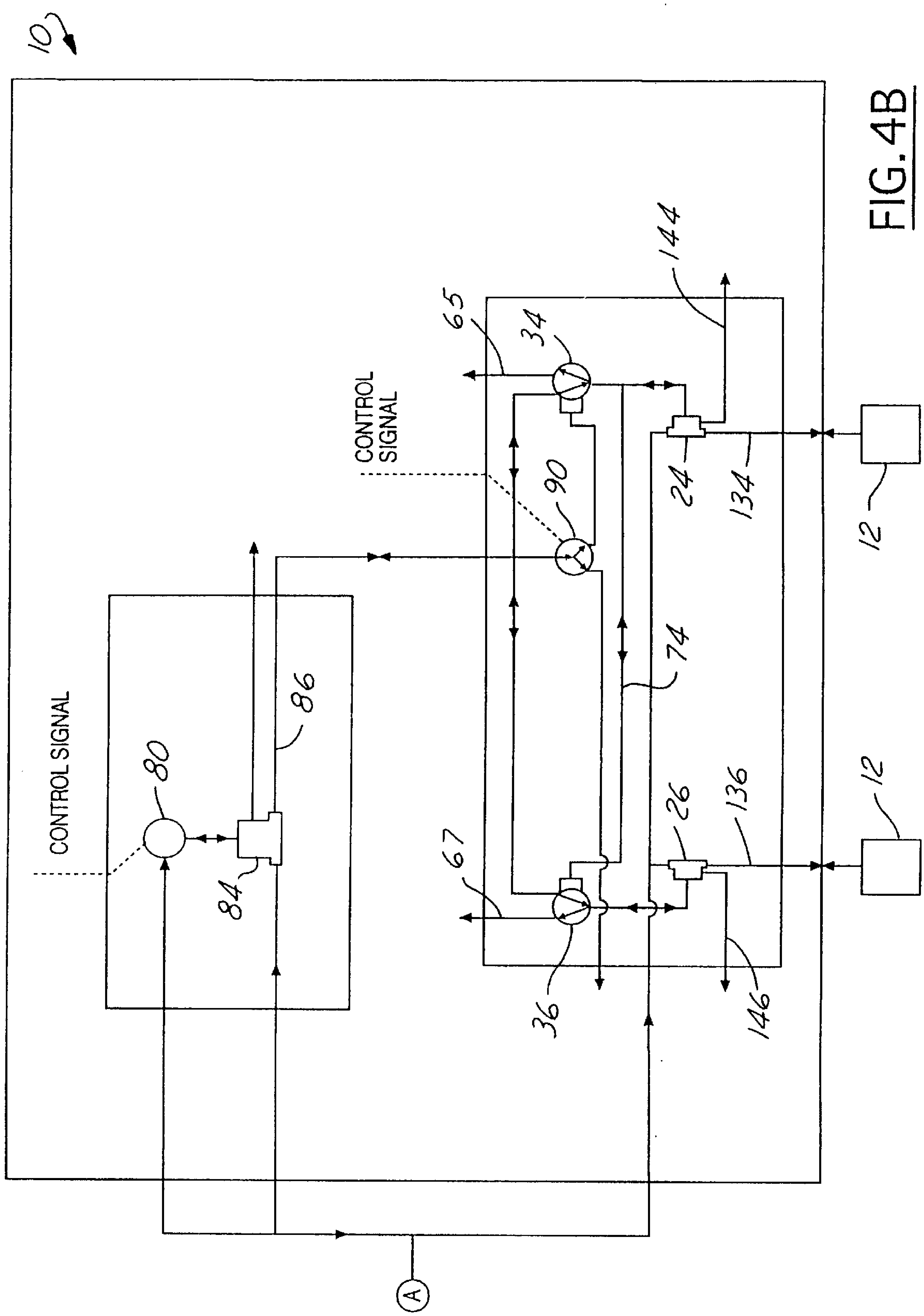

10
CONTROL SIGNAL
80
84
86
CONTROL SIGNAL
90
65
34
144
24
134
12
74
26
136
12
67
36
146
A

FIG. 4B

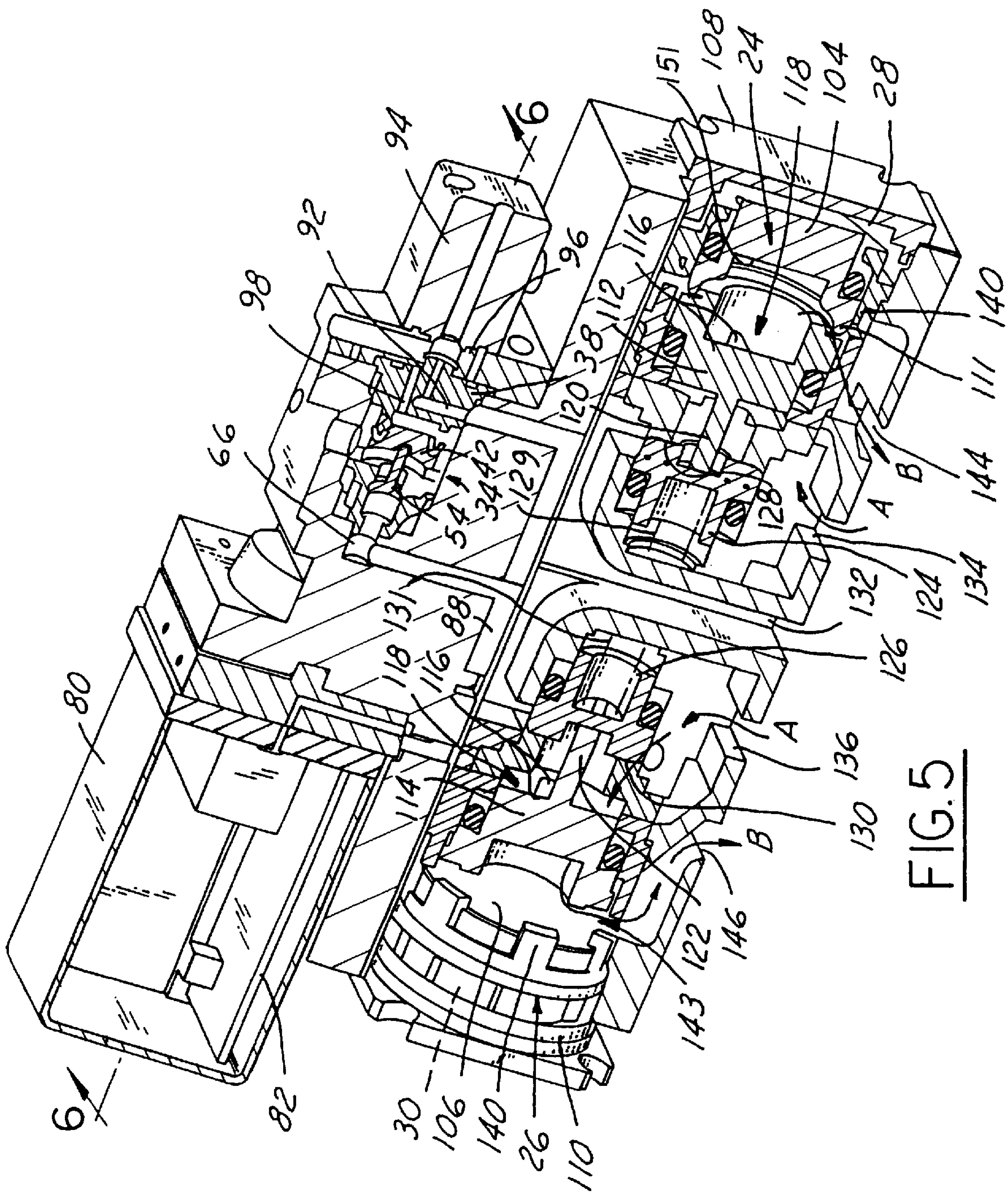


FIG. 5

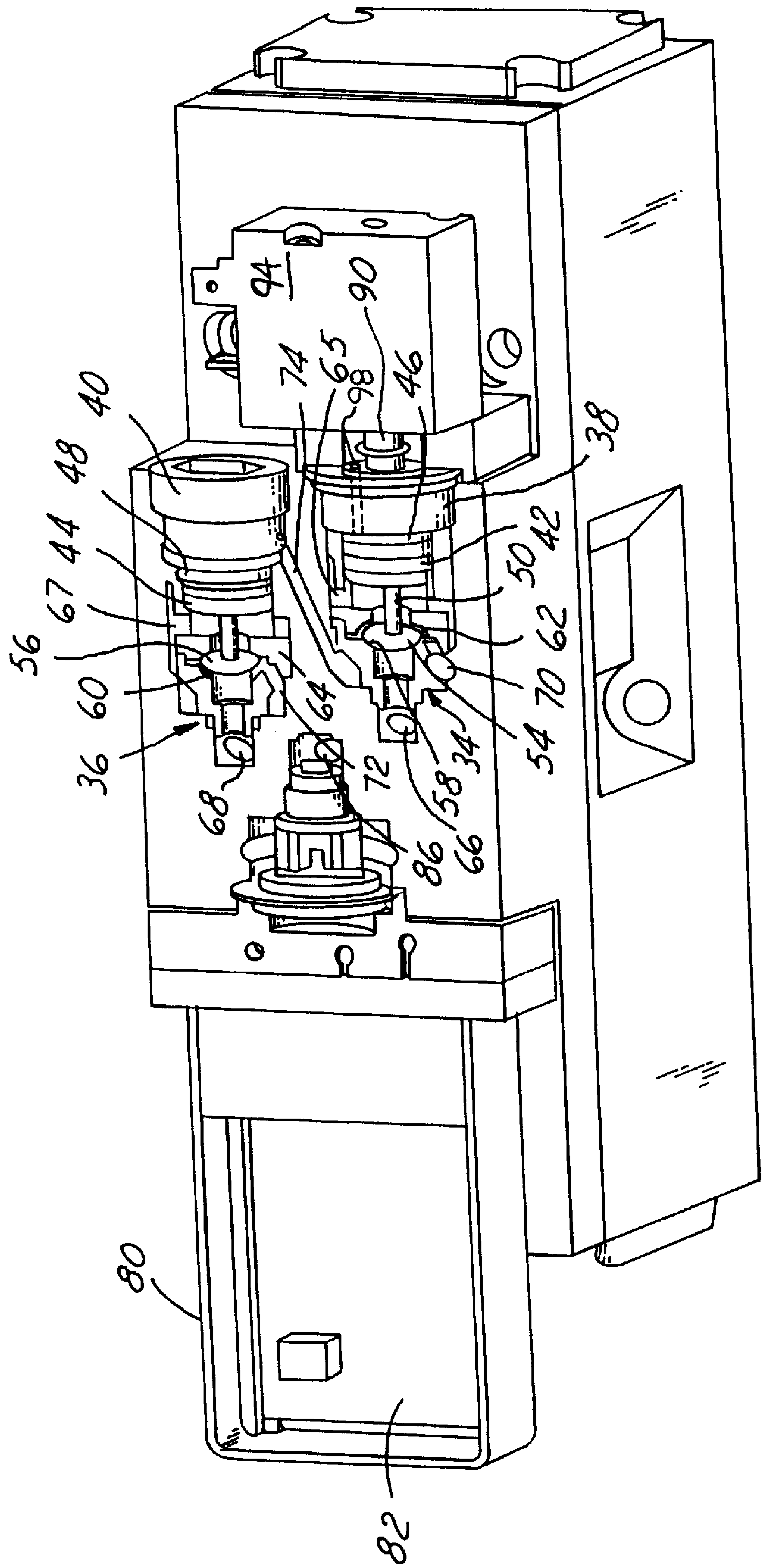

94
90
74
65
98
46
40
48
38
44
42
50
67
62
56
70
60
64
54
34
36
72
58
68
66
86
80
82

FIG.6

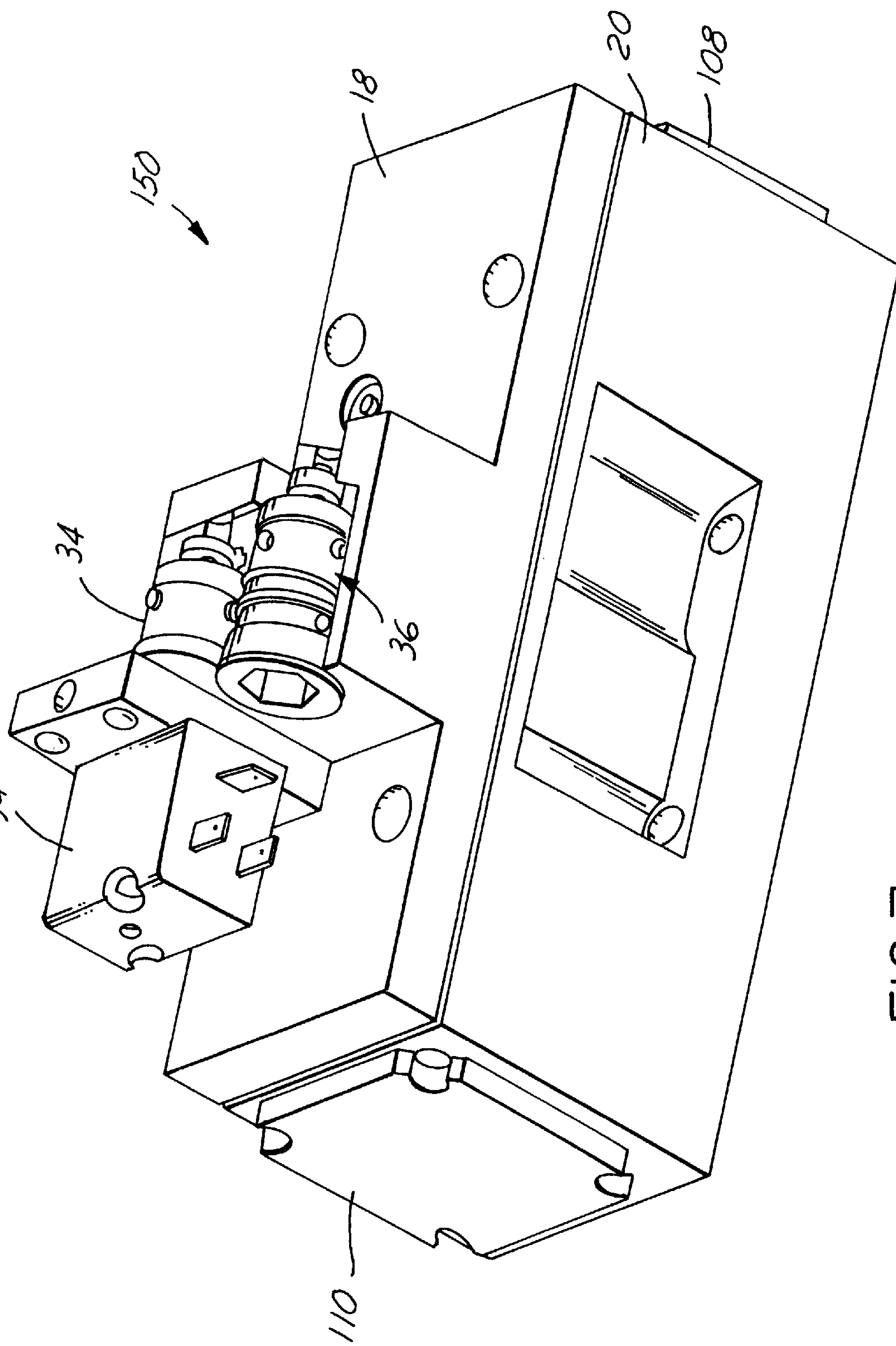


FIG. 7

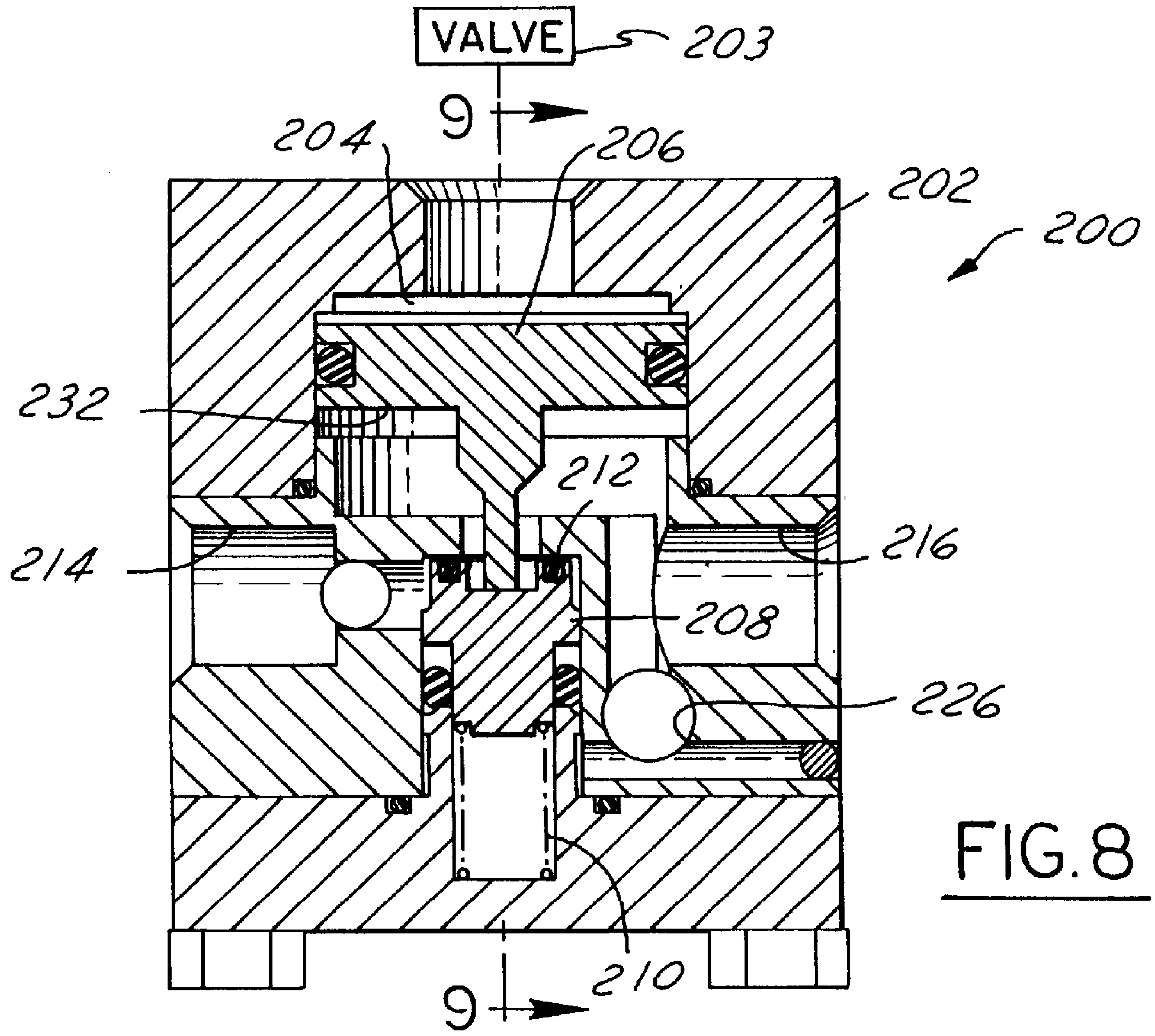

VALVE
203
9
204
206
202
200
232
212
214
216
208
226
210
9

FIG. 8

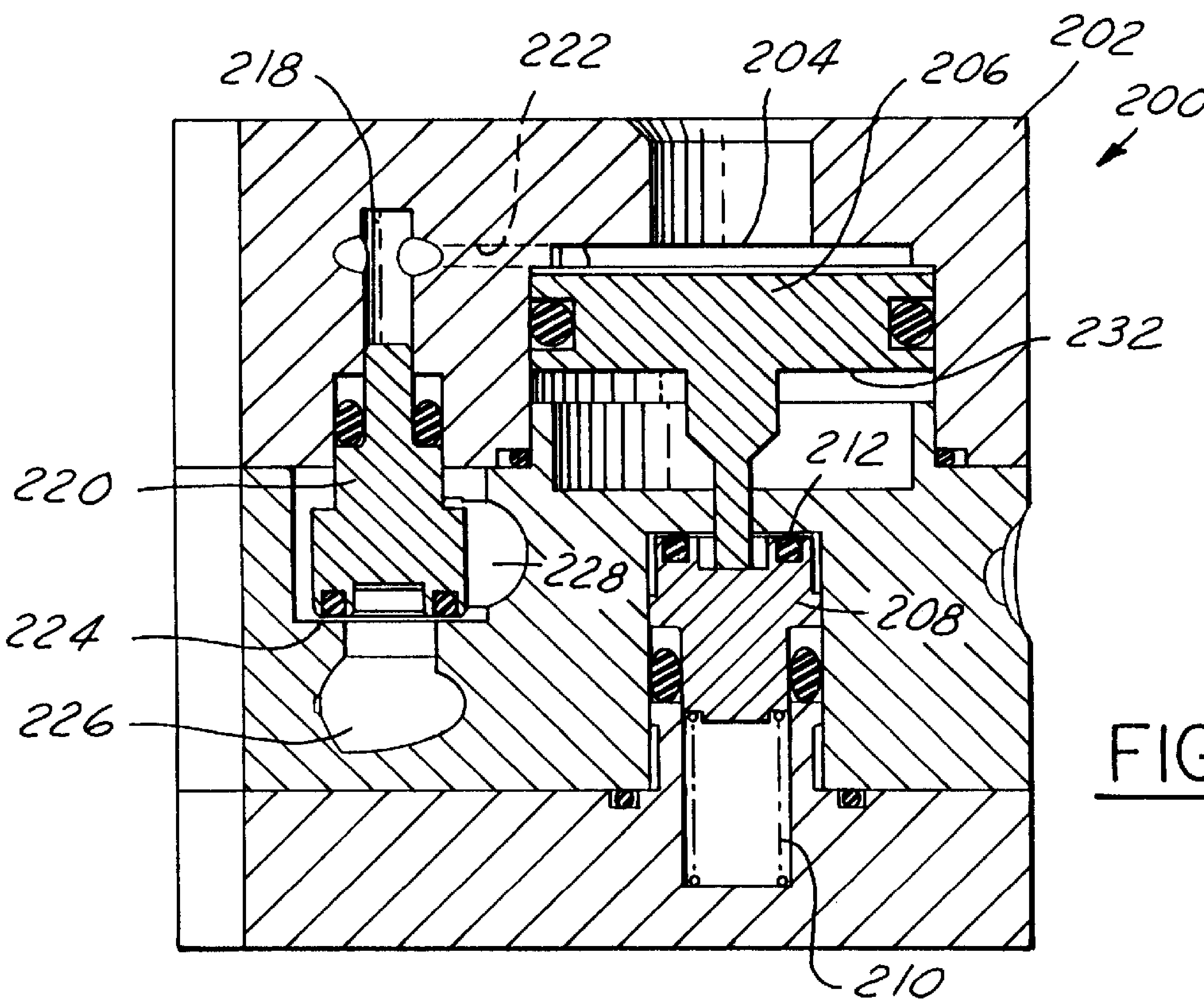

218
222
204
206
202
200
232
212
220
228
208
224
226
210

FIG. 9

PNEUMATIC PILOT-OPERATED CONTROL VALVE ASSEMBLY

FIELD OF THE INVENTION

This invention relates to control valves and more particularly to a pilot operated control valve assembly for pneumatic cylinders.

BACKGROUND OF THE INVENTION

Currently, three-way or four-way spool valves are used to control the pressurization and venting of pneumatic cylinders. Spool valves require extremely close tolerances and are therefore difficult to manufacture and assemble and are susceptible to becoming jammed within their associated valve bore during use. When jammed, the valve bore in the body and/or the spool valve itself may become damaged thereby necessitating repairing or replacing one or both of them.

Because of the close tolerances required for the operation of spool valves, they are difficult to assemble into their associated valve bores and are extremely intolerant of particulate contaminants and wear. When contaminants enter the associated valve bore of a spool valve, the spool valve or valve bore can become damaged which requires repairing or replacing the spool valve and/or the entire spool valve assembly. The spool valve can also become jammed within the valve bore due to contaminants which requires repairing or replacing the spool valve assembly which can be labor intensive and costly. Further, when used in an assembly line environment, failure of the spool valve assembly requires temporarily shutting down the assembly line to repair or replace the spool valve assembly which is time consuming and very costly.

One current use of a spool valve is to control the welding cylinders, in an automated system such as used in the automotive industry to drive a welding gun of an electrical resistance welder. The spool valve controls the pressurization of the drive cylinder which in turn controls the weld clamp jaws of the welding gun which, when clamped provides the weld to the workpiece in the clamp. Typically, this operation is automated and within an assembly line and thus, if the spool valve becomes jammed the jaws of the weld clamp can remain engaged with the workpiece and can destroy expensive parts, such as automotive bodies as well as other components of the assembly line. This also requires shutting down the assembly line to repair or replace the spool valve assembly and disengage the weld clamp jaws from the workpiece. Shutting down the assembly line is extremely costly and time consuming and repairing or replacing the spool valve assembly is labor intensive and therefore also very costly.

Further, the spool valve is only capable of responding to an on-off signal and does not provide a force which is proportional to an input signal and therefore does not provide a force which can be varied to vary the clamping force and subsequent welding force of the weld clamp. To perform this function with a spool valve, a pressure regulator must be added to the spool valve assembly which increases the complexity of the assembly and also its cost.

SUMMARY OF THE INVENTION

A pilot operated and pneumatically driven control valve assembly has a pair of pilot operated and pneumatically driven regulators to control the pressurization and venting of a pneumatic cylinder. The pilots of each regulator are alternately driven by a pair of normally open pilot operated valves each of which is in communication with a separate regulator to control the pressurization of that regulator. The pilot operated valves are alternately driven between open and closed positions to alternately drive the pilots of the regulators. The regulators communicate with a pneumatic cylinder adjacent opposed sides of a piston within the cylinder to control the pressurization of the cylinder adjacent each side of the piston. The pneumatic cylinder may be of any type with one current application used to drive the weld clamp of an electrical resistance welder such as that used in an automotive assembly line.

The pilot operated control valve assembly can be pneumatically driven such as by compressed air from an air compressor. The pressure of the air delivered to the pilot of a regulator controls the flow of air through the regulator and provides an output air pressure from the regulator which is proportional to the pressure at the pilot. With the inclusion of an air pressure regulator which can vary the pressure of air supplied to the regulator pilots, the output pressure of the regulators can be varied. The output of the air pressure regulator can be electronically controlled to permit remote operation and/or automated control of the regulators. Thus, the clamping pressure of the weld clamp in an electrical resistance welding gun can be varied by simply varying the pressure supplied to the pilots of the regulators. This allows the same control valve assembly and pneumatic cylinder to be used under varying conditions and with varying workpieces which require different weld clamp pressures.

The pilot operated valves and regulators do not require the extremely close tolerances required for spool valves and are thus easier to manufacture and assemble. Further, the pilot operated control valve assembly is more tolerant of contamination than a spool valve and when contaminated, the control valve assembly will merely experience a reduction in performance, not a total failure such as when a spool valve becomes jammed. Generally, the effect of contamination within the control valve assembly will be a slight reduction in clamping pressure and/or a slightly longer time required to open or close the weld clamp. In most cases, the pressurized air within the assembly will clear the assembly of contaminants after one cycle.

Objects, features and advantages of this invention include providing a pilot operated control valve assembly to control a pneumatic cylinder that is tolerant of contaminants, can be manufactured with large tolerances, can provide an output proportional to an input signal, fails gradually rather than abruptly like a spool valve when jammed, provides rapid pressurization and venting of the pneumatic cylinder, is readily adaptable to many pneumatic cylinder applications, is capable of rapid cycle times, is of relatively simple design and economical manufacture and assembly, is rugged, durable, reliable and has a long useful in-service life.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features and advantages of this invention will be apparent from the following detailed description of the preferred embodiments and the best mode, appended claims and accompanying drawings in which:

FIG. **1** is a diagrammatic view of a pair of control valve assemblies embodying this invention and used with an automotive type electrical resistance welder;

FIG. **2** is a plan view of a control valve assembly in FIG. **1** having a proportional control module;

FIG. **3** is a plan view of the other control valve assembly of FIG. **1**;

FIG. 4A is a circuit diagram of the control valve assembly of FIG. 3;

FIG. 4B is a circuit diagram of the control valve assembly of FIG. 2;

FIG. 5 is a cross sectional view taken along line 5—5 of FIG. 1;

FIG. 6 is a cross sectional view taken along line 6—6 of FIG. 5;

FIG. 7 is a perspective view of the control valve assembly of FIG. 3;

FIG. 8 is a cross sectional view of a regulator according to a second embodiment of the invention; and

FIG. 9 is a cross sectional view taken along line 9—9 of FIG. 8.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIGS. **1** and **2**, a control valve assembly **10** is provided to control the pressurization and venting of a pneumatic cylinder **12** which can be utilized to drive a welding clamp **14** of an electrical resistance welding gun. The pneumatic cylinder **12** preferably has a pair of pistons **11, 13** therein with one piston driven to actuate the jaws of the welding clamp **14** and the other piston driven to advance and retract the welding gun.

The control valve assembly **10** is contained within a housing **16** having a head **18** and a body **20** which interfaces with a standard automotive weld cylinder manifold **22**. The assembly **10** has two pilot operated regulators **24, 26** (FIG. **5**) driven by a pneumatic input control signal, such as air from an air compressor, which delivers pressurized air to the pilot dome **28, 30** of each pilot operated regulator, **24, 26** respectively. When the first regulator **24** is pressurized, it pressurizes a portion of the weld cylinder **12** to provide the force urging the welding tips or electrical contacts **32** of the weld clamp **14** into engagement with the workpiece. When the second regulator **26** is pressurized, it pressurizes an opposite side of the weld cylinder **12** to open the weld clamp **14** and disengage it from the workpiece.

In use, the first regulator **24** and second regulator **26** are alternately driven such that when one of them is pressurized, the other is vented to the atmosphere. To accomplish this alternate actuation of the regulators a first pilot operated valve **34** (FIG. **6**) and a second pilot operated valve **36** are provided each of which is in communication with a separate regulator, **24, 26** respectively, to control the pressurization of that regulator.

As shown in FIG. **6**, each pilot operated valve **34, 36** has a pilot dome **38, 40**, a piston **42, 44** having one face **46, 48** in communication with the pilot dome **38, 40**, a valve stem **50, 52** operably associated with the piston **42, 44** and a valve head **54, 56** attached to the valve stem **50, 52** and moveable between a first position on an upper seat **58, 60** and a second position on a lower seat **62, 64**. When pressurized air is within the pilot dome **38, 40** and acting on the face **46, 48** of the piston **42, 44**, the valve head **54, 56** is moved against its upper seat **58, 60** and a vent passage **65, 67** is opened to allow the pilot dome **28, 30** of the associated regulator **24, 26** to be vented. Each valve head **54, 56** is biased (such as by a spring, not shown) to its second position on its lower seat **62, 64** and in this position, pressurized air supplied to a valve inlet **66, 68** of each valve **34, 36** is communicated with the associated regulator pilot dome **28, 30** through a supply passage **70, 72**. The valve inlet **66** of the first pilot operated valve **34** is also communicated with the pilot dome **40** of the second pilot operated valve **36** through a connecting passage **74** to pressurize that pilot dome **40** when the valve head **54** is adjacent its lower seat **62**.

To provide an output air pressure which can be readily and remotely varied, a proportional air control module **80** is provided. The control module **80** (FIGS. **5** and **6**) has an electronic card **82** which has a variable analog control signal of between 0 to 10 volts or 4 to 20 ma to control output pressure of a pilot-operated pressure supply regulator **84** downstream of the control module **80**. The supply regulator **84** functions to control the pressure of the air supplied to the pilot operated valves **34, 36** which selectively communicate that air with the regulator pilot domes **28, 30**. Alternatively, the system can be used without a proportional air control module **80** and the supply regulator **84** can be manually adjustable to vary its output pressure. As another alternative, a pair of supply pressure regulators may be provided with each either manually or electronically controlled. In this embodiment, each regulator communicates with a separate pilot operated valve **34, 36** to separately control the pressure of compressed air delivered to each pilot operated valve **34, 36**.

As best seen in FIG. **5**, the supply regulator **84** has an outlet **86** in communication with the valve inlet **66, 68** of each pilot operated valve **34, 36** through a passage **88** between them. The supply regulator **84** also communicates with a valve **90** via a passage **92** through the pilot dome **38**. The valve **90** is driven between open and closed positions by a solenoid **94** to selectively permit air in the passage **92** to flow into a chamber **96** defined between the pilot dome **38** and solenoid **94**. Air in the chamber **96** flows into the pilot dome **38** through an opening **98** to act on the piston **42**. The solenoid driven valve **90** controls pressurization of the pilot dome **38** which thereby controls the movement of the valve head **54** to its first and second positions. Movement of the valve head **54** controls pressurization and venting of the pilot dome **28** of the first regulator **24** and also controls pressurization of the pilot dome **40** of the second pilot operated valve **36** which, in turn, controls movement of its associated valve head **56**. Movement of this valve head **56** controls the pressurization and venting of the pilot dome **30** of the second regulator **26**. Thus, the function of the control valve assembly **10** is dictated by the solenoid driven valve **90** which controls the pilot operated valves **34, 36** which in turn, alternately actuate the pilot operated regulators **24, 26**.

As shown in FIG. **5**, the pilot operated regulators **24, 26** are each received in the body **20** of the housing **16** and through the manifold **22** are in communication with the pneumatic cylinder **12** and preferably with opposed chambers in the cylinder **12** adjacent opposed faces of a piston therein. With this configuration, the regulators **24, 26** can control pressurization of the cylinder **12** to drive the piston in opposed directions to both open and close the jaws of the weld clamp **14**.

Each regulator **24, 26** has a main valve **104, 106** which defines in part its pilot dome **28, 30** and is slidably received for reciprocation in an end cap **108, 110** of the housing **16** to vary the axial size of the pilot dome **28, 30**. An annular, raised rim **111** of the main valve **104, 106** bears on a plunger body **112, 114** to displace the plunger body **112, 114** when the pilot dome **28, 30** is pressurized and the main valve **104, 106** is displaced towards the plunger body **112, 114**. The plunger body **112, 114** has a plurality of guide fibs **116** to control its axial movement and openings **118** between the fins **116** and through the plunger body **112, 114**. Each plunger body **112, 114** also has an axially extending stem **120, 122** which bears on a valve head **124, 126** which is biased to a normally closed position on a valve seat **128, 130** by a spring **129, 131**. In its closed position each valve head **124, 126** prevents supply air, which is delivered to the body **20** through a supply passage **132** in communication with each of the valve heads **124, 126**, from exiting through an outlet **134, 136** and entering the pneumatic cylinder **12**. Preferably, supply lines **138** connected to the manifold **22** communicate each outlet **134, 136** with the pneumatic cylinder **12**.

When a valve head **124, 126** is acted on by the stem **120, 122** of the plunger body **112, 114** and moved to its open position, compressed air in the supply passage **132** can flow beyond the valve head **124, 126**, through the outlet **134, 136** downstream of the valve head **124, 126** and into the pneumatic cylinder **12**. Air which flows through one outlet **134** pressurizes one chamber in the pneumatic cylinder **12** to displace the piston and cause the weld clamp **14** to close. Air which flows through the other outlet **136** pressurizes the opposite chamber of the pneumatic cylinder **12** to return the piston and thereby open the weld clamp **14**. As noted earlier, the pilot operated regulators **24, 26** are alternately driven to ensure that only one valve head **124** or **126** is open at one time so that only one chamber in the pneumatic cylinder **12** is pressurized at one time.

Each end cap **108, 110** has stand-off feet **140** extending therefrom and constructed to engage the plunger body **112, 114** when the pilot dome **28, 30** is vented and the main valve **104, 106**, plunger body **112, 114** and valve head **124, 126** return towards their original positions. When the plunger body **112, 114** engages the stand-off feet **140** the main valve **104, 106** separates from the plunger body **112, 114** providing a gap **142, 143** between them through which air in the pneumatic cylinder **12** can flow to the atmosphere through a vent passage **144, 146** along flow path A-B as shown by the arrows in FIG. **5**. This vent passage **144, 146** remains open until the pilot dome **28, 30** is again pressurized and the main valve **104, 106** is displaced into engagement with the plunger body **112, 114**. The vented air preferably flows through the manifold **22** and into filtered exhaust modules **148** connected to the manifold **22**.

As shown in FIGS. **1, 3** and **7**, a modified control valve assembly **150** can also be used in applications where the output pressure does not need to be variable. In this configuration, the control valve assembly **150** does not have a control module **80** or a supply regulator **84** and supply air from the air supply flows directly to each valve inlet **66, 68** and to the solenoid driven valve **90**. This control valve assembly **150** functions in substantially the same manner as the previously described version except that its output is essentially constant because an essentially constant pressure is delivered to the pilot domes of its regulators. As shown in FIGS. **1** and **3**, this control valve assembly **150** is used to actuate a pneumatic cylinder to advance and retract the welding gun which carries the weld clamp **14** and is useful in many other pneumatic cylinder applications where similar movement of a piston, work arm or the like is desired.

Operation of the Pilot Operated Valves

An analog control signal on the order of between 0 to 10 volts or 4 to 20 ma is provided to the electronic card **82** of the proportion air control module **80**. The control module **80** provides an output air pressure of the supply regulator **84** of between about 0 and 100 psi which is proportional to the electric input signal it receives. As shown in FIGS. **4**A and **4**B, the output of the supply regulator **84** flows to the valve inlet **66, 68** of each pilot operated valve **34, 36**, and also to the solenoid **94** which drives the first pilot operated valve **34**. The air signal provided to the inlet **68** of the second pilot operated valve **36**, which is normally open, closes that valve head **56** on its lower valve seat **64** whereupon that input air flows through the passage **72** adjacent the valve head **56** and into the pilot dome **30** of the second regulator **26**, to actuate that regulator **26** and supply air under pressure to the portion of the cylinder **12** which opens the weld clamp **14**.

A digital electric control signal is supplied to the solenoid **94** to open the normally closed solenoid driven valve **90** and allow the input air from the supply regulator **84** to flow through the solenoid driven valve **90** and into the pilot dome **38** of the first pilot operated valve **34** to act on the piston **42** therein and close the valve head **54** on its upper seat **58**. With the valve **34** in this closed position, the input signal from the supply regulator **84** is blocked and the vent passage **65** is open. The air within the pilot dome **28** of the first regulator **24**, which closes the weld clamp **14**, is vented back through the valve **34** between the valve head **54** and the piston **42** and through the vent passage **65** to the atmosphere. As described above, this allows the main valve **104**, plunger body **112** and valve head **124** to move towards the end cap **108** and eventually provide the gap **142** between the plunger body **112** and main valve **104** to open the vent passage **144** and vent to atmosphere that portion of the pneumatic cylinder **12** along flow path A-B of FIG. **5**. Thus, pressure is supplied to one side of the cylinder **12** to open the weld clamp **14** and the opposite side of the cylinder **12** which closes the weld clamp **14** is vented to the atmosphere when the first **34** and second **36** pilot operated valves are in the above described position.

To reverse the positions of the pilot operated valves **34, 36**, the solenoid driven valve **90** is closed to prevent the pressurization of the pilot dome **38** of the first pilot operated valve **34**. The compressed air at the valve inlet **66** moves the valve head **54** to its lower seat **62** thereby closing the vent passage **65**, and allowing the compressed air from the supply regulator **84** to flow through that valve **34** and to the pilot dome **28** of the first regulator **24** which closes the weld clamp **14**. With the valve **34** in this position, a portion of the output of the supply regulator **84** is also communicated to the pilot dome **40** of the second pilot operated valve **36** through the connecting passage **74** to supply air under pressure therein acting on its piston **44** to move its valve head **56** onto its upper seat **60** thereby preventing the compressed air in the valve inlet **68** from flowing to the pilot dome **30** of the second regulator **26**. This opens the vent passage **67** in the valve **36** allowing the pilot dome **30** of the second regulator **26** to vent to the atmosphere and thereby opens the vent passage **144** to vent one side of the pneumatic cylinder **12** (along flow path A-B in FIG. **5**) to avoid interfering with the force provided to close the weld clamp **14**.

Operation of the Pilot Operated Regulators

Each regulator **24, 26** functions in the same manner but in alternate relationship as driven by the pilot operated valves **34, 36** previously described. Thus, the description of only one of the regulators **24** is necessary.

Referring again to FIGS. **4** and **5**, compressed air from the air compressor is supplied through the supply passage **132** which branches to communicate with the valve head **124, 126** of each of the pilot operated regulators **24, 26** which are normally closed to prevent the air from flowing therethrough. When the air pressure is supplied to the pilot dome **28** of the first regulator **24** from the first pilot operated valve **34** as previously described, the main valve **104** is displaced which causes displacement of the plunger body **112** which bears on the valve head **124** to open it. When the valve **124** is open, the supply air flows therethrough and through the outlet **134** to pressurize the side of the cylinder **12** which closes the weld clamp **14**.

The valve head **124** remains open (displaced from the valve seat **128**) until the sum of the spring force and the air pressure downstream of the valve head **124** and acting on the interior face **151** of the main valve **104** is greater than the pressure within the pilot dome **28** whereupon the valve head **124** will close on the valve seat **128** to maintain the desired pressure in that portion of the cylinder **12**. A change in either the pressure within the pilot dome **28** or the pressure downstream of the valve head **124** results in a pressure differential within the regulator **24** which is readily and dynamically responsive to balance the forces therein and maintain the output pressure to the cylinder **12** as a function of the pilot dome **28** pressure.

For example, if the pressure in the cylinder **12** increases, that pressure, which acts on the interior face **151** of the main valve **104** will displace the main valve **104** towards the end cap **108**. The main valve **104** will separate from the plunger body **112** thereby opening the vent passage **144** to relieve the increased pressure downstream of the regulator **24** to maintain the desired pressure in the cylinder **12** as a function of the pressure in the pilot dome **28**. The vent passage **144** will remain open until the forces acting on the main valve **104** cause it to again bear on the plunger body **112**. Similarly, if the pressure supplied to the pilot dome **28** is increased, the main valve **104** will be displaced away from the end cap **108** causing the plunger body **112** to displace the valve head **124** from its valve seat **128** and permit supply air to flow through the outlet port **134**. The valve head **124** remains open until the pressure downstream of the valve head **124** and the spring force are equal to or slightly greater than the pilot dome pressure **28**. Thus, the regulators **24, 26** provide dynamic control of the pressure supplied to the cylinder **12** as a function of the pilot dome pressure to maintain the desired pressure within the cylinder **12**.

When the first pilot operated valve **34** changes position, the pilot dome **28** is vented to the atmosphere. The force of the spring **129** acting on the valve **124**, as well as the pressure of the air acting on the interior face **151** of the main valve **104** displaces the main valve **104** to decrease the size of the pilot dome **28**. The valve **124** closes the supply passage **132** to prevent pressurizing the portion of the cylinder **12** which closes the weld clamp **14**. The stand-off feet **140** provided in the end cap **108** prevent continued axial displacement of the plunger body **112**. The main valve **104** continues to be displaced thereby separating from the plunger body **112** and providing the gap **142** between them allowing air within the pneumatic cylinder **12** to vent back through the outlet **134**, through the plunger body openings **118** and through the gap **142** between the plunger body **112** and the main valve **104** to a vent passage **144** open to atmosphere (along flow path A-B of FIG. **5**). The vent passage **144** is closed when the pilot dome **28** is again pressurized and the main valve **104** is displaced until it bears on the plunger body **112**.

Because the regulators **24, 26** are alternately driven when the first regulator **24** is vented to the atmosphere, the pilot dome **30** of the second regulator **26** is pressurized to open its valve **126** and permit the supply air to pressurize the associated portion of the cylinder **12** to open the weld clamp **14**. When the state of each pilot operated valve **34, 36** is changed, the pilot dome **28** of the first regulator **24** is pressurized to open its valve **124** and close the weld clamp **14** and the second regulator **26** is vented to the atmosphere.

The pilot operated regulators **24, 26** are shown in a common housing **16**, but they may be separated with each disposed adjacent its associated side of the weld cylinder **12** or in some other desired orientation. Similarly, in an alternate embodiment of this invention, as shown in FIGS. **8** and **9**, an individual regulator **200** can be disposed in a separate housing **202** downstream of a control valve **203** which controls the delivery of pressurized air to the pilot dome **204** of the regulator **200**. In this embodiment, the pressure in the pilot dome **204** acts directly on the main valve plunger body **206** to displace a poppet valve **208** which is yieldably biased by a spring **210** to a closed position on a valve seat **212** to prevent flow of pressurized air from a supply passage **214** to an outlet port **216** downstream of the poppet valve **208**. The pressurized air in the pilot dome **204** adjacent the plunger body **206** is communicated with a separate pilot chamber **218** adjacent to a poppet vent valve **220** through a connecting passage **222**. The poppet vent valve **220** is closeable on a valve seat **224** to selectively communicate a passage **226**, which at its other end communicates with the outlet port **216**, with a vent passage **228** downstream of the poppet vent valve **220**. Thus, the forces acting on the poppet vent valve **220** are the pressure of the air in the pilot chamber **218** and the pressure of the air at the outlet port **216** of the regulator **200**.

Operation of the Second Embodiment Regulator

When pressurized air is delivered to the pilot dome **204** of the regulator **200** and also to the pilot chamber **218** of the poppet vent valve **220** via the connecting passage **222**, the plunger body **206** is displaced thereby displacing the poppet valve **208** to permit the flow of pressurized air from the supply passage **214** through the outlet port **216**. The pressure of air adjacent the outlet port **216** is communicated with the face **232** of the plunger body **206** opposite the pilot dome **204** and in combination with the force of the spring **210** acting on the poppet valve **208**, opposes the force of the pressurized air in the pilot dome **204** to control movement of the poppet valve **208**. The pressure of the air adjacent the outlet port **216** is also communicated with the poppet vent valve **220** via the passage **226** and acts on the poppet vent valve **220** in opposition to the pressurized air within its pilot chamber **218** and when greater than this force, displaces the poppet vent valve **220** opening the vent passage **228** and reducing the pressure at the outlet port **216**. As in the first embodiment, the regulator **200** controls when pressurized air is delivered through the outlet port **216** and is also dynamically responsive to control the pressure at the outlet port **216** and hence, within the pneumatic cylinder **12**. The poppet valve **208** will close on the valve seat **212** to prevent flow through the outlet port **216** when the pressure at the outlet port **216** and the force of the spring **210** are equal to or slightly greater than the air pressure within the pilot dome **204**.

The pilot driven pneumatic control valve assembly **10** provides an output which can be readily varied by varying the output pressure of the supply regulator **84** (preferably via control module **80**) to vary the pressure of air supplied to the pilot domes **28, 30** of each regulator **24, 26** and thereby control the clamping force of the weld clamp **14**. Thus, the regulators **24, 26** and **200** function to control both when pressurized air is delivered to the pneumatic cylinder **12** and the pressure at which that air is delivered to the cylinder **12**. The vent passages can also be made somewhat large thereby permitting exhaust flow equal to or greater than the primary or pressurizing flow. The system is more tolerant of contamination than spool valves and failure occurs as a gradual performance degradation rather than sudden catastrophic failure such as when a spool valve becomes jammed. Further, it should be noted that the pneumatic control valve assembly **10** can be used in any application wherein rapid pressurization and venting of a cylinder or the like is desired. For instance, as shown in FIGS. **1**, **3** and **7**, another valve assembly **150** can be used to advance and retract the welding clamp **14** in addition to opening and closing it. Because the output for this action does not need to be varied like the clamping force does, this valve assembly does not have a control module **80** or supply regulator **84**.

What is claimed is:

1. A valve assembly for delivering a supply flow of pneumatic air from a supply of pressurized air, said valve comprising:

a housing having a supply passage, an outlet passage, and an exhaust passage, said supply passage receiving supply pressure from the supply of pressurized air, said housing further having a dome passage for communicating a flow of pilot pressure from a supply of pilot pressure;

a valve head mounted in said housing and biased to a closed position against a valve seat by a biasing member;

a cylindrical main valve member and a plunger body slidably mounted in a bore of said housing, said main valve member and said plunger body movable in said bore to move said valve head to open said supply passage in response to pilot pressure in said dome passage and communicate supply pressure from said supply passage to said outlet passage and to an interior face of said main valve, said main valve slidable away from said plunger body to open said exhaust passage when a sum of said biasing force of said biasing member and said supply pressure on said interior surface of said main valve is greater than said pilot pressure in said dome passage.

2. The valve assembly of claim **1** further comprises a dome at least one stand-off foot extending outwardly in a bore to engage said plunger body to provide an exhaust gap between said main valve and said plunger body for communicating said supply pressure to said exhaust passage when said main valve is moved to open said exhaust passage.

3. The valve assembly of claim **2**, wherein said plunger body has a stem extending outwardly to engage said valve head.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,082,406
DATED : July 4, 2000
INVENTOR(S) : Felton Williamson, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Line 63 - Replace "fibs" with --fins--

Column 5,
Line 57 - Replace "Operation of the Pilot Operated Valves" with --OPERATION OF THE POILOT OPRERATED VALVES-- in bold and centered

Column 6,
Line 52 - Replace "Operation of the Pilot Operated Regulators" with --OPERATION OF THE OPERATED REGULATORS -- in bold and centered

Column 7,
Line 57 - After "driven" insert --,--

Column 8,
Line 24 - Replace "Operations of the Second Embodiment Regulator" with "OPERATION OF THE EMBODIMENT REGULATOR" in bold and centered

Signed and Sealed this

Tenth Day of July, 2001

Attest:

Nicholas P. Godici

NICHOLAS P. GODICI

Attesting Officer

Acting Director of the United States Patent and Trademark Office